Multiscale Eulerian-Lagrangian Spray Methodology Coupled with Flamelet Models for Liquid Rocket Engine Combustion, Phase I

Completed Technology Project (2018 - 2019)

Project Introduction

The innovation proposed here is a novel multi-scale coupling methodology implemented in the Loci-STREAM CFD code, for developing a high-fidelity, high-performance multiphase combustion modeling capability to enable accurate, fast and robust simulation of unsteady turbulent, reacting flows involving cryogenic propellants (such as LOX/Methane) in liquid rocket engines (LREs). During Phase 1 work, a complete Eulerian-Lagrangian spray modeling methodology will be developed. The key components of this methodology are: (a) Volume-of-Fluid (VOF) method for liquid jet core and primary atomization, (b) Transitional Breakup (TBU) model for treating large drops and ligaments resulting from primary atomization, (c) Secondary Breakup (SBU) models, (d) Lagrangian Particle Tracking Model (LPT) to track the dispersed droplets, and (e) Evaporation models. In Phase 2 work, this spray modeling methodology will be coupled to flamelet-based models in Loci-STREAM to yield a full spray combustion capability. The Transitional Breakup (TBU) model is a novel approach proposed in this project– it will allow a robust transfer of large drops from the VOF model to the LPT model. The key components of this TBU model are: (1) a cloud-of-parcels approach in which the large drops are extracted from the VOF model and injected into the LPT model as a cloud of Lagrangian parcels with a diameter equal to that of the large drop but a fractional number representing the part of the large drop that each parcel represents, and (2) a stochastic model which evaluates the probability of breakup and the size distribution of a large drop using Monte-Carlo methods. The proposed enhancements in Loci-STREAM are anticipated to yield higher fidelity and more reliable analytical/design capability relative to existing capability at NASA for turbulent reacting flows in LREs.

Anticipated Benefits

1. Design and analysis of full rocket engine combustion simulations, of relevance to NASA.
2. High-fidelity simulations of upper-stage and in-space propulsion systems, particularly LOX/Methane propulsion engines for planetary lander systems.
3. Improved understanding of ignition and combustion in LOX/Methane engines.
4. Vital component in the design process, resulting in enhanced injector designs and reductions in cost during the development cycle of new lander systems.

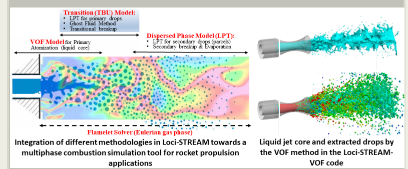

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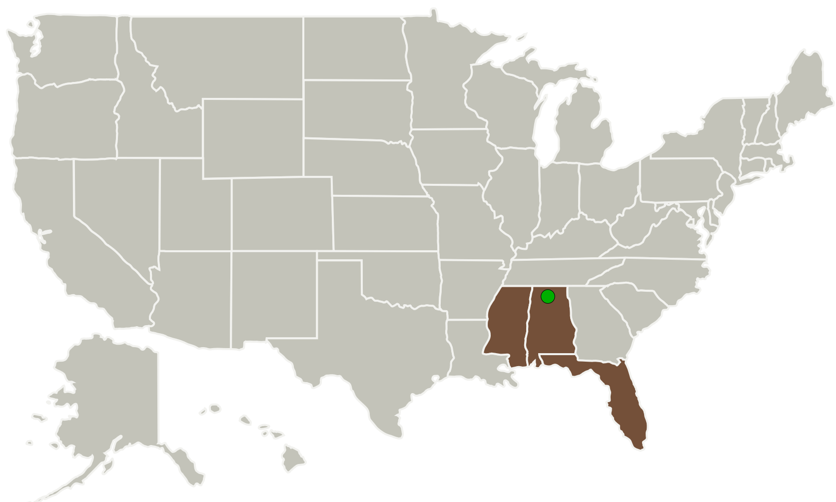
Table of Contents

1. Spray combustion methodology useful for variety of engineering applications.
2. Fast and accurate simulation for reacting flows at private companies dealing with space propulsion engines, gas turbine engines, diesel engines, etc.
3. For example, the Loci-STREAM code is being used at Aerojet Rocketdyne for gas-gas injector simulations; with the enhancements resulting from this project, the applicability of Loci-STREAM will be broadened to liquid propellant engines.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Streamline Numerics, Inc.	Lead Organization	Industry	Gainesville, Florida
Marshall Space Flight Center(MSFC)	Supporting Organization	NASA Center	Huntsville, Alabama

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Streamline Numerics, Inc.

Responsible Program:

Small Business Innovation Research/Small Business Tech Transfer

Project Management

Program Director:

Jason L Kessler

Program Manager:

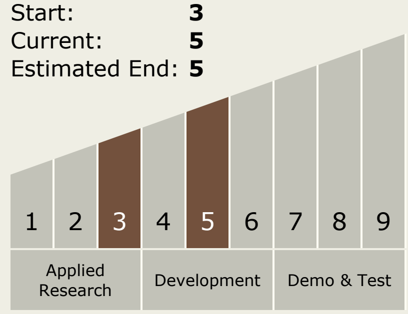
Carlos Torrez

Principal Investigator:

Siddharth S Thakur

Technology Maturity (TRL)

Start: **3**
Current: **5**
Estimated End: **5**



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Primary U.S. Work Locations	
Alabama	Florida
Mississippi	

Project Transitions

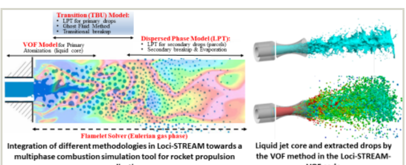
July 2018: Project Start

August 2019: Closed out

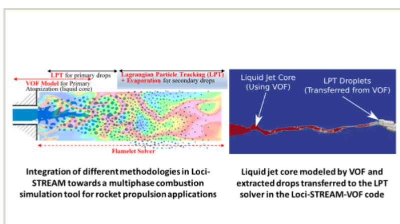
Closeout Documentation:

- Final Summary Chart*(https://techport.nasa.gov/file/137869)*

Images



Briefing Chart Image
Multiscale Eulerian-Lagrangian Spray Methodology Coupled with Flamelet Models for Liquid Rocket Engine Combustion, Phase I
(https://techport.nasa.gov/image/136195)



Final Summary Chart Image
Multiscale Eulerian-Lagrangian Spray Methodology Coupled with Flamelet Models for Liquid Rocket Engine Combustion, Phase I
(https://techport.nasa.gov/image/134997)

Technology Areas

Primary:

- TX01 Propulsion Systems
  - └ TX01.1 Chemical Space Propulsion
    - └ TX01.1.7 Cold Gas

Target Destinations

The Moon, Mars, Others Inside the Solar System